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Evaluation of Hypernatremic Dehydration in Newborns After Discharge-in a Newborn Clinic

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Abstract

Neonatal hypernatremic dehydration (NHD), a consequence of inadequate fluid intake in newborns, can cause morbidity and mortality. This study aims to evaluate the signs, symptoms, and laboratory findings of newborns with NHD and define the approaches that may help to prevent its occurrence. Eighty-five newborns (gestational age ≥37 weeks) with ≥10% weight loss and diagnosed with NHD at their first post-discharge visit were retrospectively evaluated over a five-year period. The control group consisted of 85 healthy newborns with <10% weight loss. Among the NHD group, 54.1% were female, with a mean gestational age 38.1±1.1 weeks, mean birth weight 3359±369 g, mean weight loss of 11.83±1.28%, and a mean age of 3.91±0.9 days at presentation. All mothers exclusively breastfed their infants; however, formula supplementation was significantly more common in the control group (p=0.001). The most common presenting complaints were jaundice (54.1%) and pink-orange discoloration on diapers (25.8%). The presence of black or dark green stool, urination <5 times perday, and pink or orange-stained diapers was significantly higher in the NHD group (p<0.05). Hyperbilirubinemia was also more prevalent in the NHD group (p<0.05). Only 16.5% of the mothers in the NHD group suspected insufficient milk intake. None of the newborns developed severe hypernatremia or complications. Despite breastfeeding education prior to discharge, mothers lacked sufficient knowledge about monitoring feeding adequacy. Educating mothers about signs of insufficient fluid intake, such as jaundice, infrequent urination, pink/orange-stained diapers and dark stools, and closer post-discharge monitoring of at-risk newborns, can help prevent NHD.

Keywords: Dehydration, hypernatremia, newborn

Introduction

The newborn period is a critical time for establishing coordinated care between mother and infant, as mothers learn breastfeeding techniques and how to monitor their newborn's vital signs. Breastfeeding plays a vital role in newborns' health, growth, and development, decreases the risk of infections and sudden infant death syndrome, and reduces the risk of chronic diseases such as obesity and diabetes, in the long term[1-3]. However, breastfeeding difficulties during this period may lead to complications, including hypoglycaemia, dehydration, hyperbilirubinemia, and even acute renal failure due to insufficient milk intake[4].

Newborns may lose up to 7-10% of their birth weight in the first 4-5 days; complications are more likely when weight

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loss exceeds 10%[5-7]. Hypernatremia, defined as serum sodium >145 mEq/L, is common among term newborns with feeding difficulties[8]. Hypernatremia and weight loss are closely correlated[9,10]. Insufficient milk intake, poor feeding, inadequate dilution of formula, or gastrointestinal losses can lead to neonatal hypernatremic dehydration (NHD). In the first week of life, insufficient milk intake is the most frequent cause of NHD. If untreated, it may cause cerebral oedema, intracranial haemorrhage, seizures, acute kidney injury, disseminated intravascular coagulation, and death[11-14]. Moderate to severe neurodevelopmental delay is also a possible long-term outcome[15].

Highlights

- Hypernatremic dehydration in newborns with feeding problems can lead to severe complications.
- Mothers lack sufficient knowledge about monitoring the adequacy of breastfeeding.
- This study aims to define the approaches that can help to prevent this complication.

Baby-Friendly Hospital Initiative (BFHI), launched by the World Health Organization in 1991, successfully promoted exclusive breastfeeding for the first 6 months through caregiver and maternal education[16]. However, simultaneously increasing caesarean section (C/S) rates may have inadvertently contributed to higher NHD incidence[17,18]. Despite pre-discharge instructions on breastfeeding techniques, mothers may not know how to monitor the adequacy of breastfeeding and may face life-threatening complications. This study aims to evaluate the clinical and laboratory presentation of NHD in newborns and identify preventive strategies.

Materials and Methods

We retrospectively reviewed 85 term newborns (≥37 weeks of gestation) born at Central Hospital, İstanbul, from 2018-2023, who were diagnosed with NHD at their post-discharge visit. Inclusion criteria were ≥10% weight loss and serum sodium >145 mEq/L.

Data collected included delivery mode, sex, gestational age, birth weight, weight at presentation, maternal-reported feeding history, nursing behaviour, urine and stool output, stool colour, presence of pink or orange stain in diapers, jaundice, and laboratory results (including serum electrolytes, urea, creatinine, glucose and total bilirubin levels). Stool colour was categorized as black, dark green, green, yellow-green, and yellow based on maternal description.

Routine hospital protocol includes daily weight monitoring before discharge; newborns with ≥7% weight loss receive close follow-up and supplementation as needed. The first outpatient visit occurs 48-72 hours post-discharge. At that visit, the total bilirubin levels are measured in cases of visible jaundice. In newborns with ≥10% weight loss, serum glucose levels, renal function tests, and electrolytes are also evaluated. Hypernatremia severity was categorized as mild (146-149 mEq/L), moderate (150-169 mEq/L), or severe (>170 mEq/L)[8,19].

The control group comprised 85 healthy newborns (≥37 weeks), with weight loss <10%, randomly selected from newborns admitted to the pediatrics outpatient clinic for their first routine control after discharge in the same period as the study group.

Exclusion criteria (applied to both groups) included prematurity (<37 weeks), asphyxia, sepsis, congenital anomalies, metabolic and endocrinologic disorders, congenital heart disease, diarrhoea, respiratory distress, or neonatal intensive care unit admission.

Laboratory assays were performed using the Beckman Coulter AU480 Chemistry Analyzer. UniCel DxC SYNCHRON systems Glucose reagent (GLUH), when used in conjunction with UniCel DxC 600/800 SYNCHRON system(s) and SYNCHRON systems AQUA CAL 1 and 3, is intended for the quantitative determination of serum glucose concentration. Urea reagent was used for the quantitative kinetic ultraviolet measurement of urea. Creatinine reagent is used for the quantitative measurement of serum creatinine. Total bilirubin reagent was used in conjunction with UniCel DxC 600/800 systems and SYNCHRON systems bilirubin Calibrator for the quantitative determination of serum total bilirubin concentration. ISE Electrolyte Buffer reagent and ISE Electrolyte Reference reagent, when used in conjunction with UniCel DxC 600/800 system(s) and SYNCHRON systems AQUA CAL 1, 2 and 3, are intended for the quantitative determination of serum sodium, potassium, and chloride concentration.

Approval of the conduct of the study was granted by the Beykent University Non-Interventional Clinical Research Ethics Board (approval number: E-45778635-050.99-96905, date: 15.03.2023).

Statistical Analysis

Descriptive analyses were performed, mean, standard deviation and percentages were calculated. The Kolmogorov-Smirnov test was used to determine the normal distribution of the variables. The Independent Student's t-tests and Mann-Whitney U tests were used in the analysis of independent quantitative data. The chi-square tests and Fisher's tests were used in the analysis of independent qualitative data. A Spearman's correlation test was used in defining the strength and direction of the relationship between the ranks of data. Significance was taken at the level $p<0.05$. Analyses were performed using the Statistical Package for Social Sciences version 28 (IBM SPSS Statistics).

Results

Among 85 newborns, the female to male ratio was 1.17 in the NHD group and 0.93 in the control group, ($p=0.443$). The mean weight loss was 11.83±1.28% in the NHD group, and 4.08±2.73% in the control group ($p<0.001$). The mean age on admission was 3.91±0.9 days in the NHD group, and 4.17±0.5 days in the control group ($p<0.001$) (**Table 1**).

All of the newborns in both groups were exclusively breastfed; formula supplementation was significantly higher in the control group ($p=0.001$) (**Table 2**).

Urination <5 times a day and the presence of pink-orange discoloration on diapers were more frequent in the NHD group (p<0.001) (**Table 2**).

In the NHD group, defecation pattern was recorded in 47 patients, and in the control group, 69 patients. Dark stool (black/dark green) was significantly higher in the NHD group, while yellow/yellow-green stool predominated in controls (p<0.001) (**Table 2**).

Serum total bilirubin levels were measured in 78 subjects from the NHD group and 72 subjects from the control group (**Table 2**). The mean serum total bilirubin level was significantly higher in the NHD group (p<0.001). In the NHD group, the ratio of newborns with serum total bilirubin levels above 10 mg/dL and 15 mg/dL was significantly higher than the control group (p<0.001) (**Table 2**).

Symptoms on admission were recorded in 60 of the patients in the NHD group (**Table 3**). Only 16.5% (n=14) of the mothers had suspected milk insufficiency in their babies (seven of the newborns had poor feeding, five had inconsolable crying, one had rare urination, and one had unsatisfied prolonged nursing).

The mean serum sodium was 149.9±2.9 mEq/L; serum potassium 4.4±0.6 mEq/L; serum chloride 113.9±3.5 mEq/L; serum urea 31.9 mg/dL (12-103), serum creatinine 0.48 mg/dL (0.2-0.78) in the NHD group. In the NHD group, there was mild hypernatremia in 42 (49.4%) and moderate hypernatremia in 43 (50.5%) of the infants. No patients had severe hypernatremia.

The comparison of laboratory parameters in newborns with mild and moderate hypernatremia groups is listed in **Table 4**. Serum urea and serum chloride levels were significantly higher in the NHD group with moderate hypernatremia (p=0.001). In the NHD group, there was a positive correlation between serum sodium and serum urea levels (p=0.001). No correlation was found between serum sodium and serum glucose levels. Although the mean serum total bilirubin level was significantly higher in the NHD group, no correlation was found between serum sodium and serum total bilirubin levels. Weight loss percentage was significantly higher in newborns with moderate hypernatremia (p=0.005).

Thirty-seven (43.5%) of the patients in the NHD group were admitted to the neonatal intensive care unit. The indication for hospitalization was moderate hypernatremia in 23 of the patients, hyperbilirubinemia in 6, and moderate hypernatremia + hyperbilirubinemia in 8 of the patients. However, eight of them refused hospitalization. Among the patients who refused

Table 1.
Demographic characteristics of newborns with NHD and control group

	NHD group (n=85)	Control group (n=85)	p-value
Gender (female/male) ratio	46 (54.1%)/39(45.9%)	41 (48.2%)/44 (51.7%)	0.443[1]
Gestational age (weeks)	38.1-39.6	38.3-39.3	0.581[2]
Maternal age (years)	29.0-34.0	30.0-36.0	0.224[2]
Mode of delivery (C/S/NSVD)	71 (83.5%)/14(16.5%)	69 (81.2%)/16 (18.8%)	0.687[1]
Birth weight (g)	3359±369	3346±374	0.814[3]
Admission weight (g)	2962±331	3207±347	<0.001[3]
Weight loss (%)	10.7-13.0	2.4-6.4	<0.001[2]

[1]: Chi-square test (Fisher's test) [2]: Mann-Whitney U test, [3]: Independent Student's t-test, C/S: Cesarean section, NVSD: Normal spontaneous vaginal delivery, NHD: Neonatal hypernatremic dehydration

Table 2.
Comparison of formula feeding, urination frequency, stool color, presence of urate crystals in urine, and serum total bilirubin levels in newborns with NHD and control group

		Control group		NHD group		p
		Mean ± SD/n-%		Mean ± SD/n-%		
Formula feeding	(-)	64	75.3%	80	94.1%	**0.001**[1]
	(+)	21	24.7%	5	5.9%	
Urination frequency (/day)	<4	12	14.1%	46	100.0%	<0.001[1]
	≥5	73	85.9%	0	0.0%	
Dark green		4	5.8%	24	51.0%	
Green		4	5.8%	6	12.8%	
Yellow-green		20	28.9%	1	2.1%	<0.001[1]
Yellow		39	56.5%	1	2.1%	
Black		2	2.9%	9	19.1%	
No stool		0	0%	6	12.7%	**0.001**[1]
Urate crystals	(-)	80	94.1%	40	48.7%	<0.001[1]
	(+)	5	5.9%	45	51.3%	
Serum total bilirubin (mg/dL)		9.6±3.7		12.6±3.6		<0.001[2]
Serum total bilirubin ≤10 mg/dL		35	48.6%	16	20.5%	<0.001[1]
Serum total bilirubin >15 mg/dL		4	5.6%	20	25.6%	**0.001**[1]

[1]: Chi-square test (Fisher's test) [2]: Mann-Whitney U test, SD: Standard deviation, NHD: Neonatal hypernatremic dehydration

hospitalization, 6 were followed up in the clinic and were given feeding advice, and 2 of them did not come for control. Twenty-nine patients were hospitalized and received intravenous fluids. Fourteen patients also received phototherapy. The average hospital stay was 1.2 days, and no complications were recorded. Mean serum sodium levels were 144.3±3.26 mEq/L at the end of the first day of treatment. Six patients with moderate hypernatremia (serum sodium: 150-156 mEq/L) who refused hospitalization, were followed up with feeding recommendations and did not have any complications.

Discussion

NHD is a frequent complication in newborns with inadequate fluid intake, and can be life-threatening if untreated[20,21]. The incidence was reported ranging from 0.2% to 8% in different studies[15,22-26]. These rates may change due to many factors, such as newborn follow-up policies of the country, screening facilities, and access to follow-up data after discharge. In a 2019 study, the incidence was reported as 30.9% in the first 72 hours in healthy newborns[8]. Our observed incidence of 1.1% aligns with the data of Ergenekon et al.[15] from Türkiye (1%).

Rising NHD has been attributed to increased rates of exclusive breastfeeding following the introduction of the BFHI, higher rates of C/S, as well as heightened awareness[10,17,18,27]. Butler and Trotman[24] noted increased detection of NHD post-BFHI and also stated that, as the awareness increased, one-third of the cases of NHD were recognized during the postnatal ward predischarge and therefore were less severe[18]. Pelleboer et al.[25], also, emphasized closer supervision of breastfeeding techniques in the postnatal ward, and stated that the longer mothers spend time in the postnatal ward, the more they are educated on the adequacy of breastfeeding. However, the increased costs of hospital stay and quicker recoveries after C/S have decreased the duration of stay to 24-48 hours, making closer evaluation of breastfeeding techniques more difficult[28].

In our clinic, since all newborns were discharged between 24-48 hours after birth —regardless of the mode of delivery— were diagnosed at their first visit after discharge. However, before discharge, all newborns are weighed daily, and if they lose nearly or more than 7% of their weight, they are closely monitored and provided with milk supplements as needed. Closer evaluation is emphasized for babies who experience over 7% weight loss is also emphasized in other studies[29,30]. In a study by Uras et al.[31], it is reported that 95% of the hypernatremia cases occurred above 7% weight loss. Lavagno et al.[13] reported that 96% of hypernatremia occurred above 10% weight loss, and severity increased with increasing weight loss.

Some studies have indicated that NHD can be attributed to inadequate breastfeeding, which is associated with delayed maturation of breast milk and insufficient supply, resulting in elevated serum sodium levels in breast milk[32]. It is reported that C/S delivery, primiparity, breast anomalies, delayed first breastfeeding, and advanced maternal age above 30 are risk factors in delayed lactogenesis[33]. In a cohort study in 2018, it was stated that 74.5% of the NHD cases were exclusively breastfed, 21.65% were mix-fed, and 3.9% of the formula-fed infants[8]. A study on weight loss in neonates has revealed that 10% of infants delivered vaginally and 25% of infants delivered via C/S experience a weight

Table 3.
Clinical presentation of newborns with hypernatremia

Symptoms	n	%
Jaundice	46	54.1
Pink or orange discoloration on diaper (urate crystals)	22	25.8
Inconsolable crying	8	9.4
Poor feeding	7	8.2
Increased body temperature	4	4.7
Rare urination	3	3.5
Difficulty in waking up	2	2.3
Unsatisfied prolonged nursing	2	2.3
No stool	1	1.2

Table 4.
Comparison of mild and moderate hypernatremia in terms of demographic features and laboratory tests

	Mild hypernatremia (n=42)	Moderate hypernatremia (n=43)	p-value*
Gender (female/male)	24/18	22/21	0.580
Gestational age (weeks)	38.54±1.00	38.94±1.16	0.151
Mode of delivery (C/S/NSVD)	34/8	37/6	0.527
Birth weight (g)	3369.35±397.1	3349.76±344.8	0.829
Admission weight (g)	2984.04±364.08	2941.04±303.51	0.530
Age at presentation (d)	3.80±1	4.02±0.8	0.147
Weight loss (%)	11.45±1.23	12.19±1.23	**0.005**
Serum glucose (mg/dL)	58.86±17.8	64.09±14.1	0.024
Serum urea (mg/dL)	24±11.2	40.22±21.7	**0.001**
Serum creatinine (mg/dL)	0.43±0.14	0.52±0.15	0.103
Serum potassium (mEq/L)	4.43±0.64	4.38±0.56	0.754
Serum chloride (mEq/L)	111.3±1.8	115.84±3.2	**<0.001**
Serum total bilirubin (mg/dL)	12.6±3.59	12.59±3.57	0.900

*: Mann-Whitney U test, NSVD: Normal spontaneous vaginal delivery, C/S: Cesarean section

loss exceeding 10% within the initial 72 hours of their lives[34]. Hobbs et al.[35], and Fan et al.[36] also emphasized the negative impact of C/S on breastfeeding. In our study, 83.5% of the neonates were delivered via a C/S, and the average maternal age at birth was 32.2 years. There was no significant difference in terms of mode of delivery and maternal age between the groups. However, the rate of receiving formula was significantly higher in the control group.

Iyer et al.[37] emphasized that weighing the babies at postnatal between 72-96 hours was an effective method in the early diagnosis of NHD. In a study in 2021, the mean age at presentation was 5.6 days, and 6 patients had acute renal failure, 2 had convulsions, and 1 had bradycardia[24]. In a previous study by Trotman et al.[18], the mean age at presentation was 7.4 days, and the rate of acute renal failure, death, convulsions, and intraventricular bleeding was higher by 18%. Our hospital policy is the daily weight control and examination of the baby 48-72 hours post-discharge. The mean age at presentation was 3.91 days. Serum urea levels were elevated in 33 (38.8%) of the patients; however, serum creatinine and serum potassium levels were normal. We did not observe severe hypernatremia; all the patients were discharged without any complications. In many studies where severe complications were reported, the age at presentation was higher than expected[18,20,23,25,38]. As the age at presentation increases, the severity of hypernatremia and complications tend to increase. Therefore, examination of the newborn on the fourth day after birth seems to be a reasonable time for the first assessment. Trotman et al.[18] reported that babies visited by domiciliary services had lower mean serum sodium, urea and creatinine levels, and emphasized the early control of the newborn after discharge.

In hospitals designated as baby friendly, mothers receive instructions on breastfeeding techniques and are urged to exclusively provide breast milk to their infants. However, there may be a lack of education in recognizing early signs of inadequate feeding and dehydration. Hence, it is possible for well-educated mothers desiring to adhere to exclusive breastfeeding guidelines to inadvertently overlook inadequate feeding practices.

The first sign of NHD is weight loss, and is accompanied by a decreased urine output, reduced bowel movements, and the appearance of urate crystals in urine[39-41]. Monitoring urine output is crucial for identifying poor feeding, and is emphasized in studies about NHD[42]. In our study, the NHD group exhibited a significantly higher presence of pink-orange discoloration on diapers and a significantly lower frequency of urination.

According to a study, the assessment of wet and soiled diaper counts in breastfed infants may not be a dependable measure for determining appropriate nutrition. Additionally, it was found that even neonates with a weight loss above 10% might still exhibit up to six instances of wet and dirty diapers[43]. In contrast, we found that the number of soiled diapers was significantly lower in the NHD group and the rate of black or dark green stool was significantly higher.

In Korea, a brochure was developed to guide the monitoring of exclusively breastfed newborns. Pale, odourless urination at least 4-5 times a day, 2-3 bowel movements with stool colour turning from brown to mustard yellow, and the baby being content after breastfeeding are regarded as signs of adequacy of breastfeeding[44]. In the study conducted, a significant proportion of the maternal participants showed a lack of awareness regarding the indicators associated with inadequate feeding practices and dehydration.

Infants with insufficient milk intake may also present with inconsolable crying, prolonged unsatisfied feeding, jaundice, and fever[14]. Some may not show signs of distress or appear sleepy and satisfied after feeding; however, they have difficulty waking up and can easily be overlooked. The most common presenting symptoms that we encountered were jaundice, pink or orange discoloration in urine, inconsolable crying, and poor feeding. However, only 16.5% of the mothers had suspected milk insufficiency.

Another important clinical situation associated with NHD is hyperbilirubinemia. In a review, it was reported that 45% of the hypernatremia cases developed jaundice[14]. The incidence of hyperbilirubinemia was notably elevated within our study cohort, and a positive association was observed between serum sodium and serum total bilirubin levels. According to existing literature, hypernatremia may negatively impact the functionality of the blood-brain barrier. This impairment could potentially ease the passage of bilirubin over the blood-brain barrier, consequently increasing the susceptibility to bilirubin encephalopathy[45]. In the present study, the diagnosis was established at an earlier stage in comparison to existing scholarly literature. The maximum recorded level of serum total bilirubin was 19.5 mg/dL, and none of the neonates exhibited signs of bilirubin encephalopathy. Although hypoglycaemia may be a contributing factor to poor feeding, the average serum glucose level was 61.4 mg/dL in our cases with NHD, and no correlation was found between serum glucose and serum sodium levels.

Study Limitation

A limitation of the study was its retrospective design, which resulted in missing anamnestic data for some patients; therefore, only the available data could be evaluated.

Conclusion

NHD is a frequent consequence of inadequate fluid intake in newborns, and early diagnosis is crucial for prompt management and prevention of severe complications. Education of healthcare providers and parents not only on lactation management but also on recognizing early signs of inadequate breastfeeding, like weight loss, dark colour stool, decreased frequency of urination, pink or orange-stained diapers, and jaundice, is essential. Daily pre-discharge weights and outpatient monitoring at 48-72 hours post-discharge; with special attention to infants with ≥7% weight loss, can assist in early detection and timely intervention.

Ethics

Ethics Committee Approval: Approval of the conduct of the study was granted by the Beykent University Non-Interventional Clinical Research Ethics Board (approval number: E-45778635-050.99-96905, date: 15.03.2023).

Informed Consent: Because the study was designed retrospectively no written informed consent form was obtained from the patients.

Footnotes

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